Supporting Information

Leong *et al.* 10.1073/pnas.0807698106

SI Text

Differential Scanning Calorimetry (DSC) Results (Fig. S1). Photoresist that had been exposed to our fabrication processing conditions was scraped off as a powder into aluminum pans, compression sealed, placed into a TA Instruments Q20, and heated at 3 °C/min.

Retrieval of a Dyed Glass Bead from Microgripper (Fig. S4). A microgripper was thermally triggered to capture a dyed bead through the process explained in *Methods*. Then, using magnetic manipulation in a Petri dish, we were able to mechanically agitate and extract the bead without any structural damage to the bead or the gripper.

Theoretical Model Details. ***Multilayer thin film curvature model.*** The model used to calculate joint curvature was adapted from literature (1–3). This model calculates the bending of a joint from individual layers with specified initial stress and elastic modulus. The model was adapted for 3 layers; to simulate 2 layers, the thickness of layer 3 was set to zero.

The assumptions in this model are:

(A) The layers are made of an elastically isotropic material.
(B) Strain normal to the surface is zero (plane strain conditions).
(C) Initial stress within the Cr layer is uniform.
(D) Minimal stress in the Cu and polymer layers (because the stress of these films is much lower than that of Cr, they were assumed to be zero, as a first order approximation).
(E) Stress in the Cr layer was measured via wafer bending to be ≈1.0 GPa.
(F) The elastic moduli of some metal thin films are different from bulk values. We used material properties from the literature for evaporated thin films.
(G) No thermal expansion effects are present, and all metal properties are constant over the temperature ranges used (290–313 K)

Definitions used in the model:

E, Young's (elastic) modulus; v, Poisson's ratio; t, thickness; σ^0, initial stress; ε^0, initial strain; R, radius of curvature.

Equations used in the model:

General parameters for multiple layers:

$$c = \frac{\sum_{i=1}^{n} E_i' t_i \eta_i \varepsilon_i^0}{\sum_{i=1}^{n} E_i' t_i}, \quad y_b = \frac{\sum_{i=1}^{n} E_i' t_i (y_i + y_{i-1})}{2\sum_{i=1}^{n} E_i' t_i}, \quad y_i = y_{i-1} + t_i; y_0 = 0, \quad R = \frac{2\sum_{i=1}^{n} E_i' t_i [y_i^2 + y_i y_{i-1} + y_{i-1}^2 - 3y_b(y_i + y_{i-1} - y_b)]}{3\sum_{i=1}^{n} E_i' t_i (y_i + y_{i-1} - 2y_b)(c - \eta_i \varepsilon_i^0)}.$$

For the case similar joint length/width (plane strain): $E_i' = E_i/1 - v_i^2$, $\eta_i = 1 + v_i$, $\varepsilon_i^0 = \sigma_i^0/E_i$.
For a trilayer joint: $y_1 = t_1$, $y_2 = t_1 + t_2$, $y_3 = t_1 + t_2 + t_3$,

$$c = \frac{E_1' t_1 \eta_1 \varepsilon_1^0}{E_1' t_1 + E_2' t_2 + E_3' t_3}, \quad y_b = \frac{E_1' t_1 (y_1) + E_2' t_2 (y_2 + y_1) + E_3' t_3 (y_3 + y_2)}{2(E_1' t_1 + E_2' t_2 + E_3' t_3)},$$

$$R = \frac{2\{E_1' t_1 [y_1^2 - 3y_b(y_1 - y_b)] + E_2' t_2 [y_2^2 + y_2 y_1 + y_1^2 - 3y_b(y_2 + y_1 - y_b)] + E_3' t_3 [y_3^2 + y_3 y_2 + y_2^2 - 3y_b(y_3 + y_2 - y_b)]\}}{3[E_1' t_1 (y_1 - 2y_b)(c - \eta_1 \varepsilon_1^0) + E_2' t_2 (y_2 + y_1 - 2y_b)(c) + E_3' t_3 (y_3 + y_2 - 2y_b)(c)]}.$$

1. Arora WJ, Nichol AJ, Smith HI, Barbastathis G (2006) Membrane folding to achieve three-dimensional nanostructures: Nanopatterned silicon nitride folded with stressed chromium hinges. *Appl Phys Lett* 88:0531081–0531083.
2. Nikishkov GP (2003) Curvature estimation for multilayer hinged structures with initial strains. *J Appl Phys* 94:5333–5336.
3. Bassik NB, Stern GM, Garcias DH (2008) Patterning thin film mechanical properties to drive assembly of complex 3D structures. *Adv Mater* 20:4760–4764.

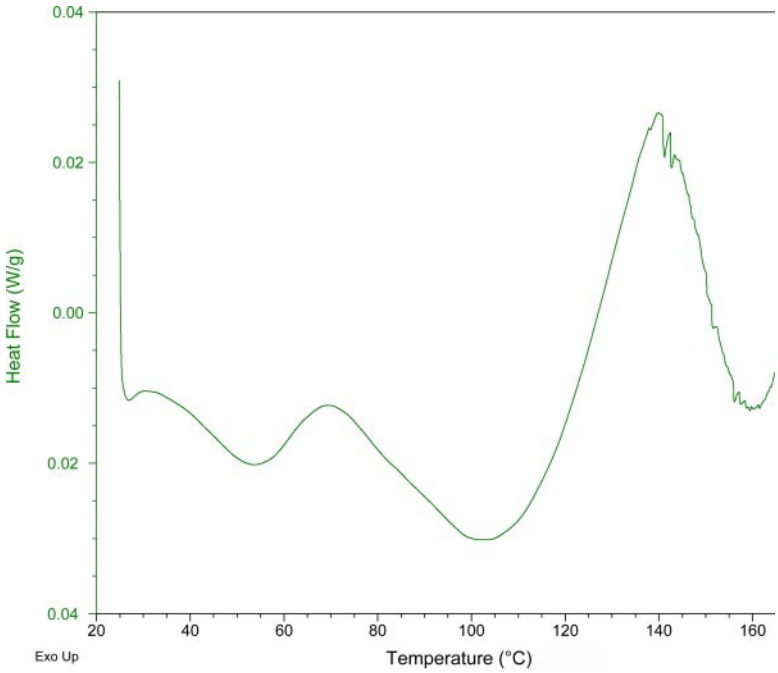


Fig. S1. DSC results.

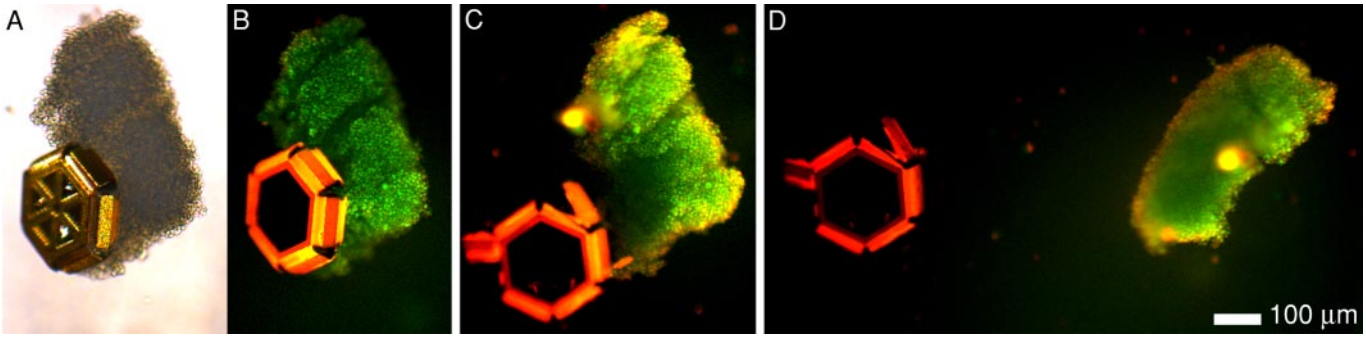


Fig. S2. Viable cells from thermally triggered capture experiment. (*A*) Bright-field optical micrograph of a microgripper with captured cells. (*B*) (Also featured as Fig. 4*G*) Fluorescent micrograph of the gripper in *A* showing that the captured cells stained with LIVE/DEAD dye were alive (green). (*C* and *D*) Fluorescent micrograph showing that most of the cells could be removed from the microgripper and remain viable. (*D*) Fluorescent micrograph with the viable cells removed further away from the claw than in *C*.

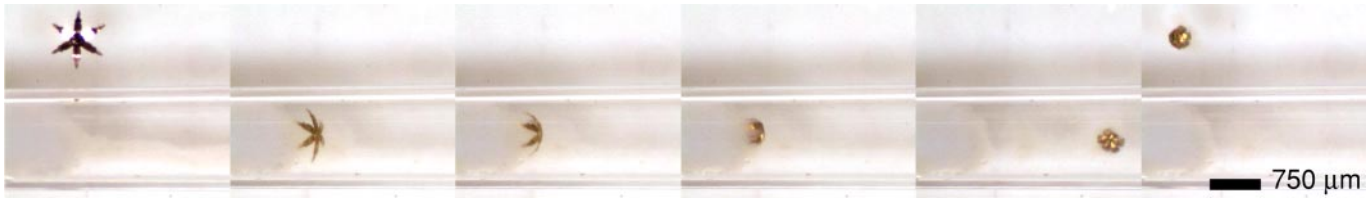


Fig. S3. Optical micrograph video sequence depicting the thermally triggered retrieval of cells from a bovine bladder sample loaded into a glass capillary tube.

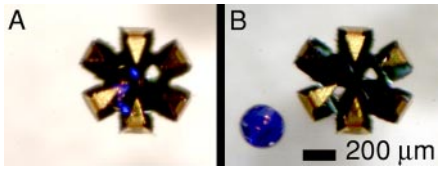
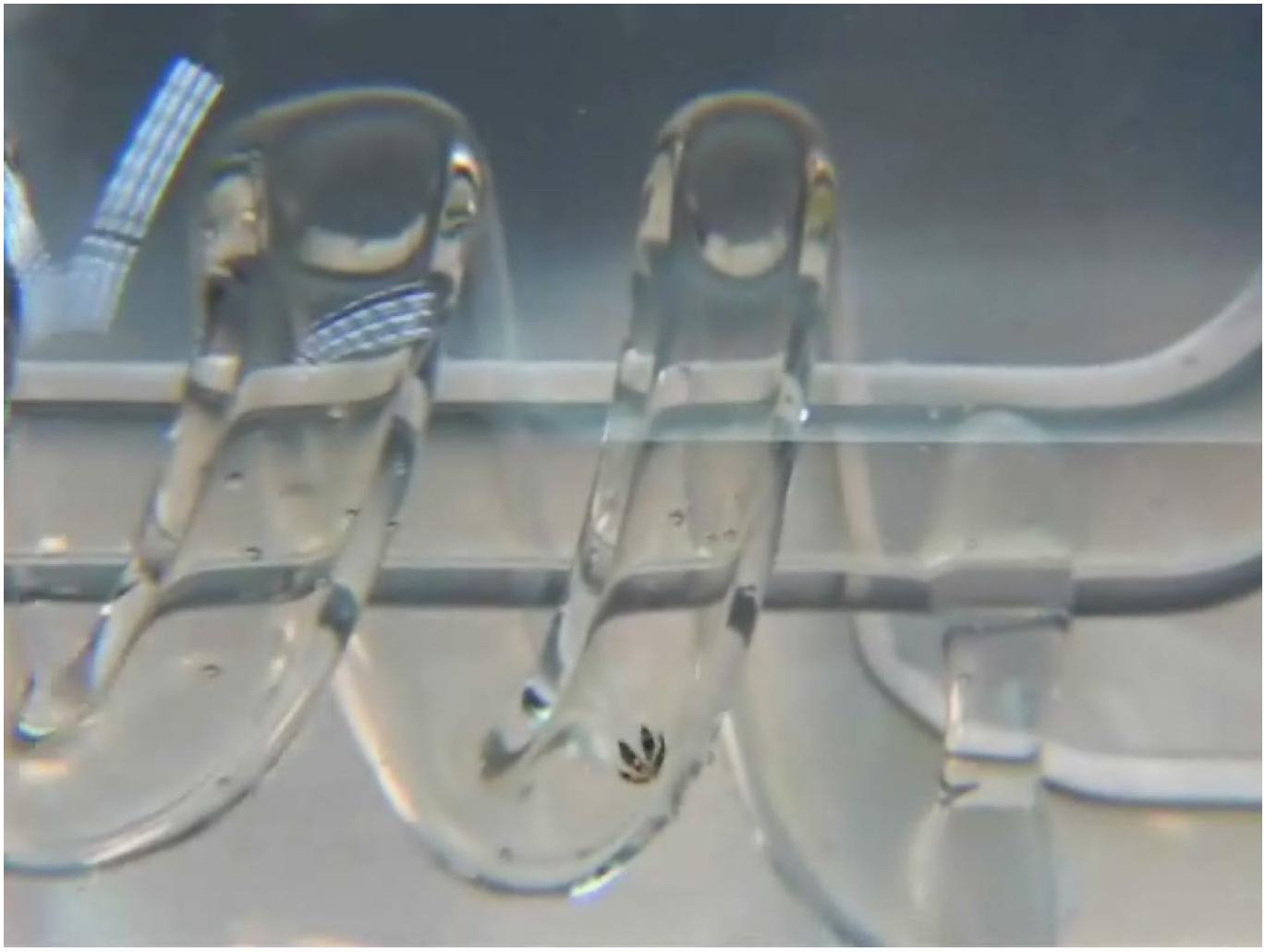


Fig. S4. Retrieval of a dyed glass bead from microgripper. A thermally triggered microgripper containing a dyed blue glass bead (*A*) was induced to release the bead after mechanical agitation with a magnet (*B*).

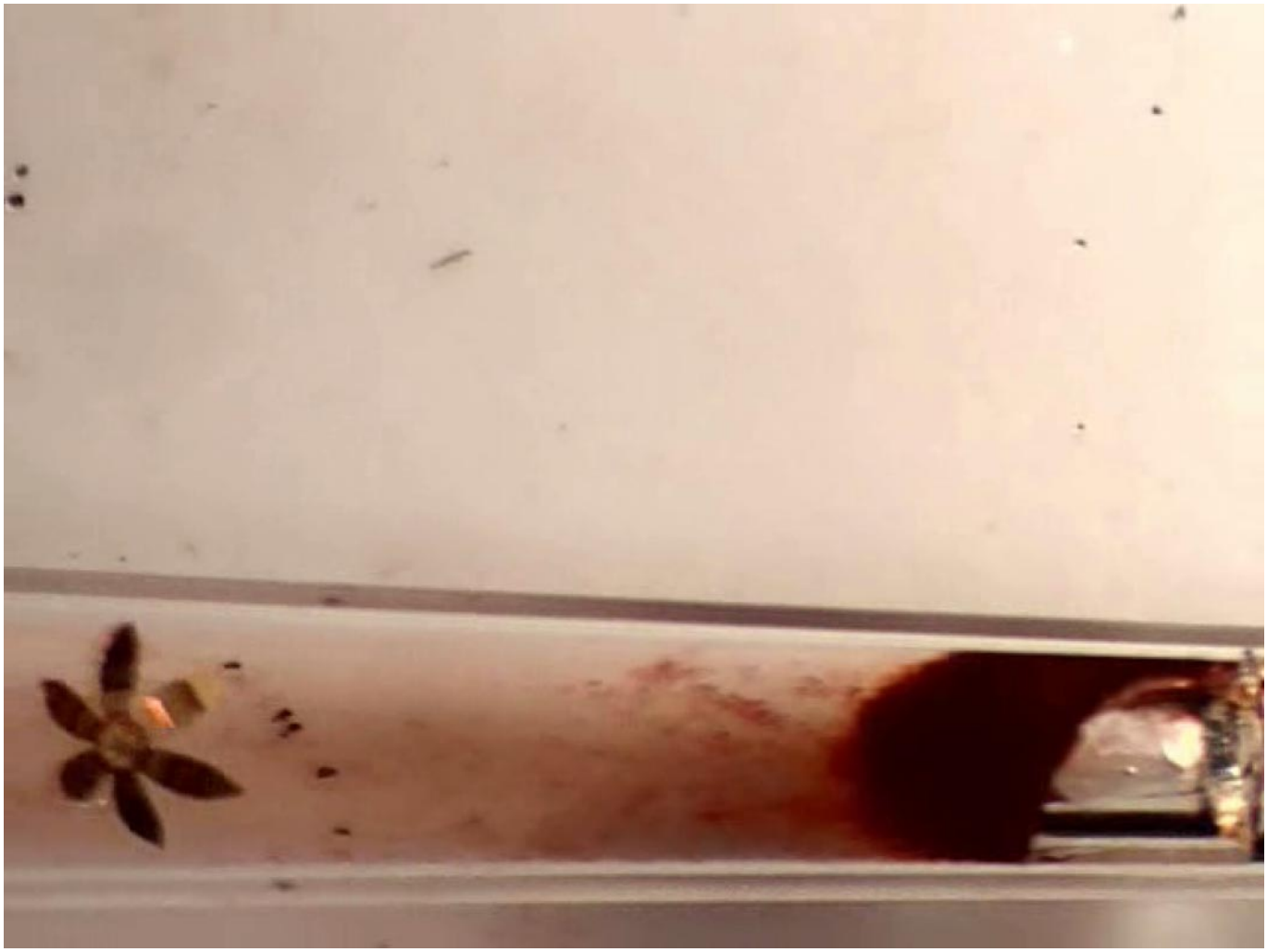


Movie S1. Remote manipulation of a microgripper through a coiled tube. To show the ease of manipulating a microgripper in a situation that would limit a tethered structure, a glass distillation column was set up as a coiled tube for the microgripper to move through. By using 2 magnets, the microgripper was successfully guided from one opening of the spiral tube to the other. The movie is 10× real-time. A time-lapse overlay of this movie is shown in Fig. 4.

Movie S1 (AVI)

Movie S2. Microgripper thermally actuated to capture a dyed bead. Shown is a dish with a small number of dyed beads in an aqueous medium. A microgripper is remotely moved toward a blue bead by using a magnetic stylus. Once over the bead, the microgripper is triggered to close by slightly heating the solution. After capture, the microgripper with bead is moved away by using the magnetic stylus. The bead is held within the phalanges of the microgripper and can be moved around for retrieval. The movie is 6× real-time.

Movie S2 (AVI)



Movie S3. Thermally actuated capture and retrieval of a cell mass from a 1.5-mm tube. This movie demonstrates the remote manipulation of a microgripper into a capillary tube (accessible only at one end) and retrieval of a cell mass that is dyed with Neutral red stain. The movie is 10× real-time and highlights the applicability of the microgripper to capture living cells. A capture sequence from this movie is shown in Fig. 5.

Movie S3 (AVI)

Table S1. Biochemicals commonly used with biological experiments, tested for biochemical triggering of the microgrippers

	Biochemical Actuation	
Chemical	25 °C (room temperature)	37 °C (body temperature)
PBS	None	Partial
Nonessential amino acids	None	None
Ventricular Myocyte Media	None	Complete
L-glutamine (2 mM)	Partial	Complete
L929 Media	Partial	Complete
Minimum Essential Media	Partial	Complete
Glucose (2.43 M)	Partial	Complete
Trypsin	Partial	Complete
Sodium pyruvate	None	Partial
HEPES	Partial	Partial
Ascorbic acid (18.2 mM)	None	Partial

The response is tabulated by one of 3 observations: None: no closing of the gripper; Partial: partial closing of the gripper, and Complete: complete closing of the gripper. All chemicals were purchased from Sigma and used at stock concentrations unless otherwise noted. The results at 37° C were performed in an incubator.